DESIGN AND SIMULATION AUTOMOBILE ACTIVE SUSPENSION SYSTEM

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DESIGN AND SIMULATION AUTOMOBILE ACTIVE SUSPENSION SYSTEM

MOHD ASQALANI BIN NAHARUDIN

A report submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2008

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive

Signature

Name of Supervisor:
Position:
Date:

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Name of Panel:
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Date:

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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In the name of ALLAH SWT, the most Gracious, who has given me the strength and ability to complete this study. All perfect praises belong to ALLAH SWT, lord of the universe. May His blessing upon the prophet Muhammad SAW and member of his family and companions.

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ABSTRACT

The purpose of this project is to design and simulate a semi-active suspension system for a quarter car model by controlling two input, spring stiffness, k_s, and damper rate, b_s. The performance of this system will be compared with the passive suspension system. There are two parameters to be observed in this study namely, the sprung mass acceleration and the suspension distortion. The performance of this system will be determined by performing computer simulations using the MATLAB and SIMULINK toolbox. For the first experiment, the damper rate was set to constant while spring stiffness was set from 10507 N/m to 131345 N/m. at lower spring stiffness leads improvement in ride quality but increased the suspension distortion at lower time. At second experiment, the spring stiffness was set to constant while the damper rate was from 1000 N.sec/m to 1400 N.sec/m. Increases in damper rate improve the ride quality but slower roll-off will occurred. In the third experiment, the damper rate value was set to maximum while spring stiffness was set to minimum to achieve optimal performance. The simulation results show that the semi-active system could provide significant improvements in the ride quality and road handling compare with the passive system.

ABSTRAK

Tujuan projek ini adalah mereka bentuk dan simulasi satu separa aktif sistem suspensi untuk satu perempat model kereta dengan kawalan dua input, melompat kekakuan, k_s, dan kadar penyerap, b_s. Prestasi sistem ini akan dibanding dengan sistem suspensi pasif. Terdapat dua parameter untuk diperhatikan dalam kajian ini yakni, pecutan besar-besaran dan melompat dan herotan suspensi. Prestasi sistem ini akan ditentukan dengan menggunakan simulasi komputer menggunakan peti alat MATLAB dan SIMULINK. Untuk eksperiment pertama, kadar penyerap dijadikan pemalar manakala nilai kadar keanjalan spring dari 10507 N/m ke 131345 N/m. Pada nilai keanjalan spring rendah memberikan peningkatan dalam kualiti pemanduan tetapi herotan suspense meninggi pada kemudian masa. Bagi eksperimen kedua, keanjalan spring dijadikan pemalar manakala nilai kadar penyerap dari 1000 N.sec/m ke 1400 N.sec/m. Kenaikan pada kadar penyerapmeningkatkan kualiti pemanduan tetapi ‘slower roll-off’ akan terjadi. Dalam eksperimen ketiga, kadar penyerap menggunakan nilai maksimum manakala keanjalan spring menggunakan nilai minimum untuk mendapat prestasi optimum. Hasil simulasi menunjukkan bahawa separa aktif sistem boleh memberikan peningkatan penting dalam kualiti pemanduan dan pengendalian kenderaan berbanding sistem pasif.

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LIST OF SYMBOLS

z_s	Sprung mass displacement
z_u	Unsprung mass displacement
z_r	Road profile input
m_s	Sprung mass
m_u	Unsprung mass
k_s	Spring stiffness
b_s	Damper rate
k_t	Tire stiffness

LIST OF ABBREVIATIONS

AF	adaptive fuzzy
AFC	active force control
DOF	degree-of-freedom
FLC	FUZZY LOGIC CONTROLLER
HJB	Hamilton-Jacobi-Belman
LQ	Linear Quadratic
LQG	Linear Quadratic Gaussian
LQR	Linear Quadratic Regulator
MR	magneto rheological
ONNC	Optimal Neural Network Controller
PI	proportional-integral
PID	Proportional Integral Derivative

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

A car suspension system is the mechanism that physically separates the car body from the wheels of the car. The performance of the suspension system has been greatly increased due to increasing vehicle capabilities. In order to achieve a good suspension system, several performance characteristics have to be considered [1]. These characteristics deal with the regulation of body movement, the regulation of suspension movement and the force distribution. Ideally the suspension should isolate the body from road disturbances and inertial disturbances associated with cornering and braking or acceleration. The suspension must also be able to minimize the vertical force transmitted to the passengers for their comfort.

This objective can be achieved by minimizing the vertical car body acceleration. An excessive wheel travel will result in non-optimum attitude of tire relative to the road that will cause poor handling and adhesion. Furthermore, to maintain good handling characteristic, the optimum tire-to-road contact must be maintained on four wheels. In conventional suspension system, these characteristics are conflicting and do not meet all conditions. Automotive researchers have studied the suspension on the system extensively through both analysis and experiments. The main goal of the study is to improve the traditional design trade-off between ride and road handling by directly controlling the suspension forces to suit with the performance characteristics .

Suspension systems can be categorized as passive, semi-active, and full-active suspensions system. Passive system consists of conventional components with spring and damping (shock absorber) properties which are time-invariant. Passive element can only store energy for some portion of a suspension cycle (springs) or dissipate energy (shock absorbers). No external energy is directly supplied to this type of suspension. Semi-active suspensions contain spring and damping elements, the properties of which can be changed by an external control. A signal or external power is supplied to these systems for purpose of changing the properties. Full-active suspensions incorporate actuators to generate the desired forces in the suspension. The actuators are normally hydraulic cylinders. External power is required to operate the system .

1.2 PROBLEM STATEMENT

The suspension system that commonly applied on the vehicle is a passive suspension system in which its spring stiffness and dumping value is constant. In the passive suspension system it dumping system has not yet gives a high performance where its vibration amplitude still high and the time required terminating the vibration is quite longer. To overcome this condition, it is then introduced a semi-active suspension and active suspension system. Unfortunately the active suspension system requires larger energy and less economizly, so then the semi-active suspension become a better choice to keep the quality of the car comfortable on any road condition.

1.3 OBJECTIVES OF STUDY

The objectives of this research are as follows:

a) To design an active suspension for a quarter car model
b) To simulate the designed active suspension system by manipulating 2 parameters; spring stiffness and damper rate.

1.4 SCOPES OF WORK

The scopes of work for this study are as follows:

a) Study on semi-active suspension system for a quarter car model and the Fuzzy Logic controller used in the system
b) Design the system by using MATLAB/SIMULINK
c) Simulate the system using MATLAB/SIMULINK

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

With a reference from various source such as books, journal, notes, thesis and internet literature review has been carry out to collect all information related to this project. This chapter discussed about semi-active suspension system for a quarter car model that will be designed and simulated by using software Matlab/Simulink.

2.2 SEMI-ACTIVE SUSPENSION SYSTEM

A semi-active suspension system utilizes a variable damper or other variable dissipation component in the automotive suspension. An example of a variable dissipater is a twin tube viscous damper in which the damping coefficient can be varied by changing the diameter of the orifice in a piston.

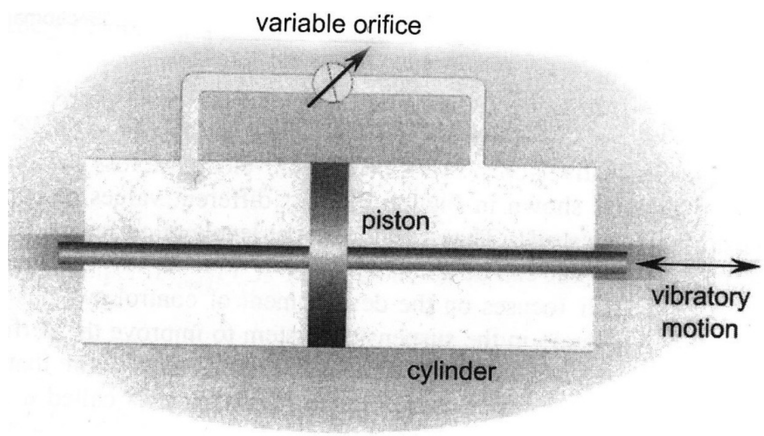

Figure 2.1 Schematic of a variable damper

Another example of semi-active dissipater is a magneto rheological (MR) damper which used MR fluid. MR fluids are materials that respond to an applied magnetic field with a change in rheological behavior. Typically, this change is manifested by the development of a yield stress that monotically increases with applied magnetic field the dissipative force provided by the damper can be controlled by controlling the electromagnetic field.

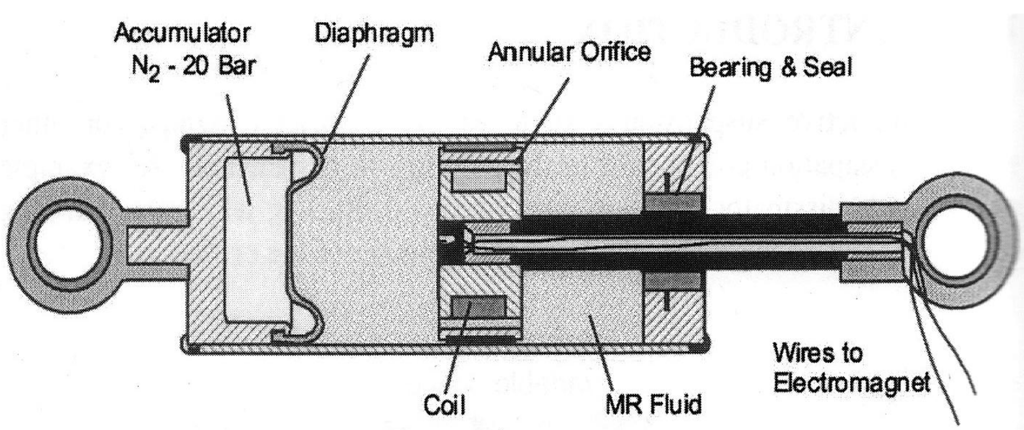

Figure 2.2 Commercial linear MR fluid-based damper

Compared to fully active suspension systems, semi-active systems consume significantly less power. The power consumption in a semi-active system is only for purpose of changing the real time dissipative force characteristics of the semi-active device. For example, power is used to change the area of the piston orifice in a variable opening damper or to change the current in the electromagnetic coil of a MR damper. External power is not directly used to counter vibratory forces. Semi-active systems cannot cause the suspension system to become unstable unlike active systems. This is due to the fact that they do not actively supply energy to the vibratory suspension system but only dissipate energy from it. [2]

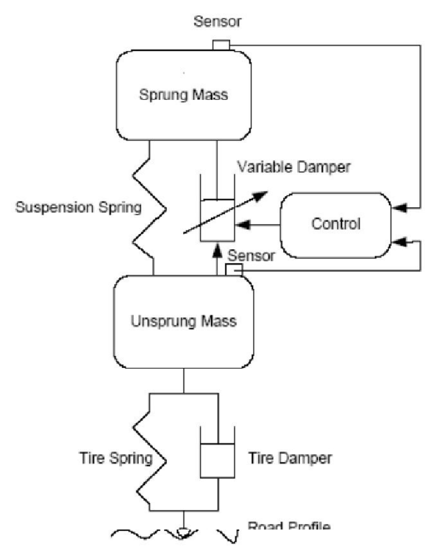

Figure 2.3 Schematic of semi-active suspension system

2.3 QUARTER CAR MODEL

A two-degree-of-freedom (DOF) “quarter-car” automotive suspension system is shown in Figure 2.4. It represents the automotive system at each wheel i.e. the motion of the axle and of the vehicle body at any one of the four wheels of the vehicle. The suspension itself is shown to consist of a spring k_s, a damper b_s and a variable damper b_{semi}. The variable damper b_{semi} can be set to zero in a passive suspension. The sprung mass m_s represents the quarter-car equivalent of the vehicle body mass. The unsprung mass m_u represents the equivalent mass due to the axle and tire. The vertical stiffness of the tire is represented by the spring k_t. the variables z_s, z_u and z_r represent the vertical displacements from static equilibrium of the sprung mass, unsprung mass and the road respectively.

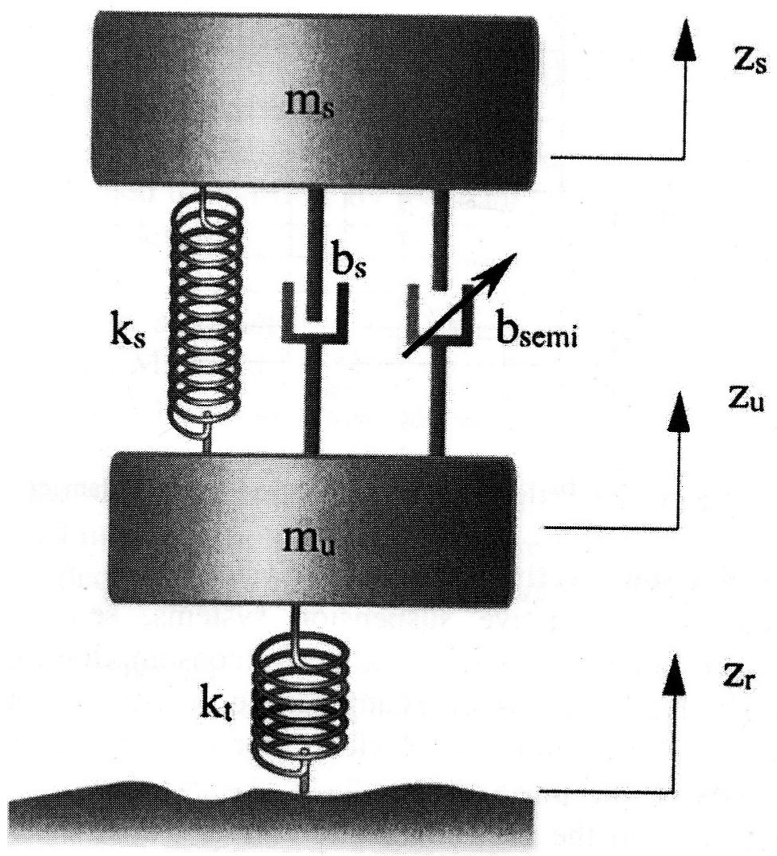

Figure 2.4 Quarter-car active suspension system

2.4 CONTROL SYSTEM

A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems.

There are two common classes of control systems, with many variations and combinations: logic or sequential controls, and feedback or linear controls. There is also fuzzy logic, which attempts to combine some of the design simplicity of logic with the utility of linear control. Some devices or systems are inherently not controllable.

The term "control system" may be applied to the essentially manual controls that allow an operator to, for example, close and open a hydraulic press, where the logic requires that it cannot be moved unless safety guards are in place.

An automatic sequential control system may trigger a series of mechanical actuators in the correct sequence to perform a task. For example various electric and pneumatic transducers may fold and glue a cardboard box, fill it with product and then seal it in an automatic packaging machine.

In the case of linear feedback systems, a control loop, including sensors, control algorithms and actuators, is arranged in such a fashion as to try to regulate a variable at a setpoint or reference value. An example of this may increase the fuel supply to a furnace when a measured temperature drops. Proportional Integral Derivative (PID) controllers are common and effective in cases such as this. Control systems that include some sensing of the results they are trying to achieve are making use of feedback and so can, to some extent, adapt to varying circumstances. Open-loop control systems do not directly make use of feedback, but run only in pre-arranged ways.